THE MEDICAL CONSEQUENCES OF NUCLEAR WAR

The Harvard Medical School
Nuclear War Study Group
A statement prepared by Robin Avery, Ezekiel Emanuel, and Philip K. Lane.

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I. INTRODUCTION

Thirty-seven years ago the citizens of the world learned of the horrors of nuclear war. The experiences of Hiroshima and Nagasaki demonstrated the catastrophic medical consequences of a nuclear explosion. As physicians, medical students, health care professionals, and medical scientists, we are compelled to express our concern over the growing risks and the medical consequences of nuclear war.

"Little Boy," the 13 kiloton bomb dropped on Hiroshima, killed 75,000 people out of a population of 245,000.(6) Within a one-and-a-half mile radius of the explosion, a shock wave and an intense firestorm destroyed every physical structure, and tens of thousands of people were severely burned. Many of the 100,000 injured people were afflicted with a disease never before encountered in history: radiation sickness.

Among the Hiroshima survivors, radiation sickness induced sloughing of skin, loss of hair, bloody diarrheas, fever, loss of appetite, and listlessness. For some, severe radiation exposure led to death within hours to days; others survived and experienced this lingering, debilitating disease over the course of years. With 90% of the medical personnel killed or injured, and most hospitals destroyed, few victims received any medical care until outside medical units arrived days after the explosion.

One bomb in one day killed 30% of Hiroshima's population and injured an additional 40% of the inhabitants. Today, world nuclear arsenals contain over one million times the destructive power of the original Hiroshima bomb.(17) Daily, ever more sophisticated nuclear weapons are being developed not only for deterrence but also for planned use in conflicts ranging from battlefield strikes to strategic nuclear wars.

This unrestrained growth of nuclear arsenals has recently been accompanied by high-level government statements condoning "limited" nuclear exchanges as acceptable military options. Contemplating the use of nuclear weapons in "limited" scenarios represents a dangerous revision in military doctrine which multiplies the risk of nuclear holocaust.

The memory of Hiroshima records the catastrophic results of a single, comparatively small nuclear weapon. The possibilities become more terrible with the realization that every detonated bomb, no matter how "limited" its intended effect might be, carries with it the inherent probability of escalation to an all-out nuclear war. The results of such a war would be measured in hundreds of millions of deaths, and would cause additional millions of burns, blast injuries, radiation poisonings, and infections. A general nuclear war would destroy any hope for effective medical treatment for the injured, and would create a vast array of long-term health disasters including increased cancer rates, genetic damage, and birth defects. The effects of such a holocaust, though calculable, are beyond comprehension.

As health professionals, we have dedicated our lives to the alleviation of suffering, to the prevention and cure of diseases, and to the nurturing of productive, fulfilling human life. Nuclear war is contradictory to the essential spirit of medicine and health care.

This statement reviews the medical consequences of nuclear explosions in several different scenarios of military conflict. Consequences described include immediate deaths and injuries due to blast, burns, and radiation, and long-term cancer epidemics, genetic effects, and environmental damage. The scope of these consequences demands an immediate effort to reduce the imminent threat of nuclear war. Our responsibility as health professionals and our duty as concerned citizens compel us to undertake this reconsideration and public declaration.

II. NUCLEAR ARSENALS

The size of a nuclear weapon is measured in tons of TNT that would cause an equivalent explosion. A one kiloton bomb is thus the equivalent of 1000 tons of TNT. A one megaton bomb is as powerful as one million tons of TNT, or 77 times more powerful than the bomb dropped on Hiroshima. It is difficult to visualize one million tons of TNT: it would fill a freight train 200 miles long.(16)

On August 6, 1945, a 13 kiloton nuclear device was exploded above Hiroshima. Since that time, the nuclear superpowers have constructed an average of four nuclear warheads a day.(17) Today, nations with nuclear weapons have over 50,000 nuclear warheads with an explosion potential of 20,000 million tons of TNT.(17) This is the equivalent of four tons of TNT for every man, woman, and child in the world.

India's explosion of a nuclear device in 1974 brought the number of nuclear weapon states to six: China, Great Britain, France, India, the United States, and the Soviet Union. Other nations reportedly close to testing their own nuclear weapons include Argentina, Brazil, Iraq, Israel, Pakistan, South Africa, and South Korea.

These increases have been paralleled by increases in technical sophistication of the weaponry. Both the U.S. and the U.S.S.R. have deployed missiles with multiple independently targeted nuclear warheads (MIRVs), which can be guided to explode within a few hundred feet of their separate targets. In addition, both superpowers continue to develop mobile missiles, highly accurate low-flying cruise missiles, and other delivery systems for nuclear weapons.

Proliferation in the size of nuclear arsenals and in the number of nuclear weapon states, and continuing technical improvements in the nuclear weapon delivery systems, rapidly accelerate the arms race.

III. THE MEDICAL CONSEQUENCES OF NUCLEAR WAR

Predicting the effects of nuclear war is a task of overwhelming magnitude. The Congressional Office of Technology Assessment (OTA) points out that "the effects of a nuclear war that cannot be calculated are at least as important as those for which calculations are attempted."(14) Quantification gives only the illusion of comprehensibility.

A nuclear exchange would be qualitatively different from any conventional war ever fought. The essential difference is that a nuclear weapon causes massive destruction instantaneously; it does not allow for the process of rebuilding between isolated events of damage, as could occur in a conventional war. In addition, a nuclear explosion poses problems unique in the history of health care: radiation sickness, burn and blast injuries on an unprecedented scale, compounded by the near-total destruction of health care facilities. In contrast to conventional weapons, the effects of a nuclear explosion persist far beyond the time of detonation. Fallout, radioactive contamination, and environmental damage surround the site of a nuclear blast for years to come. For these and other reasons, "the surviving nation would be far weaker—economically, socially, and politically— than one would calculate by adding up the surviving economic assets and the numbers and skills of the surviving people."(14)

The following sections describe the immediate, short-, and long-range consequences of a nuclear war.

A. Immediate Effects: Hours to Days

Military experts have attempted numerous technical studies predicting the number of deaths and injuries resulting from nuclear explosions. Although such predictions are quantified, it is important to recognize that the scale of injury and suffering would be unprecedented in human experience.

The following subsections present an account of the mortality, types of injury, and the quality of health care after a nuclear war.

1. Mortality

A one megaton bomb would scorch an area of 100 square miles. If dropped on a city the size of Detroit, it would kill half a million people.(14)

A 10-20 megaton bomb dropped on New York City, exploding above Times Square, would destroy all buildings in Manhattan and almost all buildings in the Bronx, Brooklyn, and Queens, and would inflict severe damage as far as Hoboken and Jersey City. The detonation would kill or injure between 5 and 10 million people.(17) The damage and number of deaths would be substantially higher if 10 one-megaton bombs were detonated instead of one 10-megaton bomb.(9)

A "limited theatre nuclear war" is a military option currently being examined as a NATO response to a possible Soviet invasion of Western Europe with conventional armed forces. Even if only 1% of current nuclear arsenals were launched by the U.S. and the U.S.S.R. to destroy military and nuclear missile installations, at least 6 to 7 million civilian deaths would result.(17)

A counterforce attack aimed at U.S. ICBM silos would kill between 2 and 20 million Americans even though the silos are located in rural areas of low population density. This uncertainty is attributable to variable wind and weather conditions, which affect fallout patterns.(14)

An all-out nuclear war, with detonation of bombs totaling 10,000 megatons (approximately half of the combined U.S. and U.S.S.R. arsenals) would kill between 35 and 77% of the United States population, or 70 to 160 million people. A comparable number of deaths would occur in the U.S.S.R.(14) In contrast, the deaths of U.S. citizens in all past wars have amounted to 1 million people.(15)

2. Blast Injuries

A nuclear explosion would lead to numerous blast-induced injuries. For example, in a one-megaton explosion over Boston, an overpressure of ten pounds per square inch and winds of 300 miles per hour would destroy all stone and concrete buildings within a radius of three miles.(8) Rubble and debris from collapsed buildings would be swept up by such winds, and airborne glass, beams, and bricks would account for further injuries within a radius of eight miles.(8) Typical blast injuries include lacerations, fractures, ruptures of internal organs, and gaping wounds of the skull, chest, and abdomen. The bomb would create an expanding pressure wave, rupturing eardrums and lungs.

3. Burn Injuries

A nuclear explosion releases thermal energy, which could ignite the city into a firestorm, as at Hiroshima. Such a firestorm melts glass and metal and ignites houses, buildings, foliage, oil tanks, and gasoline. This raging fire would cause severe burns of the skin, eyes, mouth, and lungs to an enormous number of inhabitants.

A one megaton bomb dropped on a city the size of Detroit would cause third-degree burns, which destroy skin tissue, out to a radius of five miles from the detonation center.(14) A 10-20 megaton bomb dropped on New York City would cause second-degree burns to inhabitants at a distance of 26 miles, reaching into Connecticut, New Jersey, and upstate New York.(17) Persons with second-degree burns over 30% of their bodies will go into serious shock, and will require hospitalization for sedation, oxygen, antibiotics, large amounts of in-

travenous fluids, and intense supportive care.(14)

A one megaton nuclear explosion over a single U.S. city would cause burn injuries in the tens of thousands.(14) Under optimal conditions, the entire U.S. hospital system could accommodate no more than 2000 severe burn victims.(14) Treatment for a single seriously burned victim costs between $200,000 and $400,000.(4)

4. Radiation Sickness

Radiation kills replicating cells. Cells of the blood, skin, hair follicles, and lining of the stomach and intestines normally replicate continuously. Consequently, the symptoms of radiation sickness are nausea, diarrhea, diffuse bleeding, hair loss, anorexia, general malaise, and weakness. The effects of other medical disorders, such as burns or blast injuries, are aggravated by radiation sickness. Depending on the amount of radiation exposure, the victims can die within days or suffer from chronic lingering sickness.

A unique problem of radiation injury is that the symptoms are the same over a wide range of exposures. Effective medical care is further complicated by the fact that mental stress from the bombing and from crowding into shelters would induce psychosomatic illness with nausea, malaise, and other symptoms similar to radiation sickness. Thus, following a nuclear explosion, it would be impossible for the physician to distinguish between a person who had received a fatal radiation dose, a person who had received a smaller dose and could survive with proper care, and a person with psychosomatic illness.(11)

A 10 megaton nuclear explosion in the center of a city the size of Boston would induce radiation sickness in approximately 1 million people.(9) Proper treatment, which consists of bed rest, good nutrition, a sanitary environment, and intravenous fluid replacement, would be unavailable after the destruction of hospitals and incapacitation of hospital personnel in such an explosion.

5. Delivery of Health Care

In the immediate aftermath of a nuclear war, modern medical care would be impossible. There would be catastrophic damage to hospitals, power plants, transportation, and communication systems, compounded by severe shortages of food, water, and shelter. In addition, the electromagnetic pulse (EMP) caused by a nuclear explosion would probably burn out the electrical equipment in any surviving hospitals.(14) There would be no antibiotics, sterile dressings, blood plasma, or other necessary supplies. Most of the health care personnel would be among the injured or dead; at Hiroshima, 90% of the physicians and nurses were unable to provide medical care.(6)

If a one megaton bomb were dropped on Detroit, there would be only 5000 beds in undamaged hospitals to treat the 500,000 injured.(14) If the victims of such a blast could be transported to hospitals throughout the entire United States (a highly unrealistic assumption), they would occupy fully 35% of the 1,407,000 beds available.(14) There is no question that most injured persons would never see a doctor, and many would die without relief of pain.

The surviving physicians will face profound dilemmas. They must choose who to treat while deciding if their primary responsibility is to prolong life or to ease pain. Ethical questions will arise on a scale unprecedented in the physicians' experience, which will demand life-or-death decisions without benefit of reflection.(12)

B. Short-Term Effects: Weeks To Months

1. Medical Complications

Care for burn and trauma victims will be complicated by radiation sickness, which depletes the body's white blood cells and thus lowers resistance to infection. A sublethal dose of 100 rem (4000 times the radiation exposure of a chest X-ray) increases the mortality of burn victims eight-fold.(12) (A radiation dose of 450 rem would kill half of those exposed.) In a general nuclear war, with 60 million injured (excluding immediate deaths), 30 million people would experience radia-

tion sickness, 20 million people would experience trauma and burns, and 10 million people would experience all these effects.(7)

2. Epidemics

Lack of facilities for sewage and garbage disposal, pollution of public water supplies, and particularly the large number of decomposing dead bodies would constitute grave threats to public health, especially for those already injured. Malnutrition combined with lack of shelter and heat would reduce disease resistance and lead to more deaths.

Bacteria, viruses, fungi, and the insects which carry them are all highly resistant to radiation, and would thrive in the post-attack period. The nuclear war survivors would suffer from decreased resistance to infection due to radiation sickness and weakness. Epidemics of previously controllable infectious diseases would be rampant. In addition, microorganisms which do not normally cause disease in humans would take advantage of the immune suppression of radiation sickness to cause outbreaks of new diseases.

3. Psychological Trauma

In the immediate aftermath, a crisis mentality would prevail; at Hiroshima, people "temporarily lost their normal mental capacities and, thus reduced to the lowest level of animal behavior, were dominated by their physical functions."(3) Many individuals would be incapable of the decisive, rational, coordinated actions necessary to survive a crisis.

Reactions of panic, violence, and competition for limited food, water, and medical resources might be anticipated. "Demoralization of the surviving population may well occur, and could result in erratic, non-social behaviour, aggressiveness or apathy...Political, legal, and monetary institutions would, if they survive, most likely be severely weakened and it is in doubt whether an organized central control could be maintained."(17)

4. Civil Defense

There has been substantial recent interest in civil defense planning, especially concerning civilian bomb shelters. A city under nuclear attack would probably experience an uncontrollable firestorm with temperatures in excess of 1000 degrees F. In these circumstances, as illustrated by the fire bomb ing of Dresden, civil defense shelters become crematoria; depletion of oxygen and toxic levels of carbon monoxide would suffocate those occupants surviving the initial fires.(5) Moreover, most civil defense shelters are not designed for long-term occupancy, yet people in shelters as far as 30 miles downwind from a one megaton explosion would not be able to emerge safely for at least 110 days.(2) At this distance, in a shelter which would screen out 90% of the radiation from the fallout, occupants would still be exposed to levels high enough to cause radiation sickness.(2) With limited supplies, lack of sanitation, and psychological trauma, post-attack circumstances in such a shelter would preclude effective medical care. The United Nations study on nuclear weapons summarized the value of civil defense planning by saying that "to nullify or substantially invalidate the nuclear threat against civilian targets by the provision of adequate shelters for the population and the hardening of industrial structures is in practice impossible."(17)

5. Prospects for Recovery

Even in an attack on a single city, help from the outside would not be immediately available due to destroyed roads, bridges, and rail links. Lingering high levels of radiation would further hinder rescue attempts. Many of the injured would die, and the public health problems described above would continue for a considerable time. Economic reconstruction would be an enormous task. "The most important fact is then that a simple addition of casualties or destroyed facilities would not give a true picture of the extent of the devastation...With five major cities obliterated simultaneously and casualties running to perhaps 10 percent of the nation's population, both the physical capacity and the psychological strength to launch such an effort might be in doubt."(17)

In the case of a large-scale war, the delicate balance among the various specialized sectors of the economy would be completely destroyed, precluding any immediate reconstruction efforts. "Considering the complexity and interdependence of industrialized society, the shortage of food, energy, transportation, human resources, various machines and vehicles, and complex electronic and electrical systems, and considering as well the disorganization, the human despair and social disruption from starvation, illness, and other traumatic experiences, it is obvious that the enormous task of rebuilding will not be attained within many years—if it ever will."(17)

C. Long-Term Effects: Years to Centuries

Long-term effects in the years and centuries following a nuclear conflict are highly unpredictable. In the most optimistic estimate, the number of long-term deaths from cancer and genetic damage would be an appreciable fraction of the immediate deaths following a nuclear conflict—"millions compared to tens or hundreds of millions."(14) At the other extreme, nuclear war could lead to extensive changes in climate and weather, damaging the earth's ecological system so as to produce adverse effects equaling or exceeding immediate effects.

The long-term effects which can be quantified are presented below. However, those effects which cannot be calculated are at least as important as those which are calculable. Large-scale nuclear war has never occurred, and the actual consequences, though real, are largely unknown.

1. Disabilities

Based on the experiences of Hiroshima and Nagasaki, the individuals who survive a nuclear conflict would carry with them a number of scars. Burn victims would be left with substantial keloid scars, a fibrous tissue which restricts movement. Survivors of blast damage would suffer from crushed limbs, amputations, blindness, deafness, and paralysis. Those exposed to sublethal radiation doses would have lowered white cell counts, reduced resistance to infection, and lingering radiation sickness for some years after exposure.(3) Anemia due to lowered red cell counts would severely handicap the survivors' capacity for physical activity.(3)

Furthermore, many Hiroshima and Nagasaki survivors experienced severe psychological trauma, characterized as a "psychic closing off...merged with feelings of depression and despair."(10) Survivors of a nuclear war might well see little purpose in living. Such psychological trauma on a large scale could critically block the social reorganization necessary for reconstruction and survival.

2. Cancer

Radiation from a nuclear explosion or from the resulting radioactive fallout would cause cancer deaths considerably above normal rates over at least the following forty years. Half of these deaths would be from leukemia, breast cancer, lung cancer, and intestinal cancer; the remaining half from other types of cancer.(14)

The Congressional Office of Technology Assessment estimates that a comprehensive nuclear war would result in 2 to 15 million eventual worldwide cancer deaths (compared to 120 to 260 million immediate deaths).(14) In general, long-term cancer deaths from a nuclear war would be on the order of 2 to 10 percent of the immediate deaths.

3. Genetic Damage

The children of women exposed to radiation during pregnancy would suffer genetic damage including stillbirths, crippling birth defects, and mental retardation. Exposure of normal adults to sublethal radiation doses in Hiroshima and Nagasaki caused distinct chromosomal abnormalities whose long-term effects are not yet assessed. However, such effects may include increased rates of abnormal births in subsequent generations.(14)

There are large uncertainties in these predictions,

but genetic injuries resulting from nuclear conflict are probably of the same order of magnitude as eventual cancer deaths—that is, 2 to 10 percent of the immediate deaths.(17) Thus, cancer and genetic damage will contribute 4 to 20 percent additional casualties above and beyond immediate deaths from a nuclear war.

4. Ecological Damage

The irreversible adverse effects of a general nuclear war on the global environment are not predictable, because the physical and biological processes involved are poorly understood. The ecological damage might be slight; or the environment could be so altered as to preclude human survival. The following environmental effects are, at best, informed guesses.

By releasing nitrogen oxides, a general nuclear conflict could deplete the Earth's ozone layer substantially. This layer normally blocks the sun's ultraviolet (UV) rays. In the five or so years required before natural restoration of the layer occurs, increased UV levels would lead to increased rates of skin cancer, blindness in many animal species, and increased rates of genetic mutation in animals and plants. The U.S. National Academy of Science in 1975 conservatively estimated that a nuclear war would reduce the ozone layer by 30 to 70 percent; more recent studies have predicted both less and more severe depletion.(14) Such depletion could cause atmospheric cooling, leading to long-term weather changes.(17)

The most damaging ecological impact of a general nuclear conflict might concern the ocean's stocks of algae. Algae live primarily in the top several meters of the world's oceans, lakes, and rivers. By photosynthesis, these organisms provide 80 percent of the atmospheric oxygen, and they are the first step in the complex food chain which feeds all other life. If the algae were damaged by increased UV exposure due to depletion of the ozone layer, the resulting ecological disruption could prove incompatible with the survival of humans and other life forms.(16)

A general nuclear conflict would also release 10 to 100 million tons of particulate matter into the upper atmosphere, an amount similar to the Krakatoa volcano eruption.(17) By reflecting the sun's rays, this debris could also induce a climatic cooling trend. If such processes led to a one degree (Centigrade) cooling in average temperature, the frost-free growing season in countries in the temperature latitudes, including Canada, the U.S., and the U.S.S.R., could be severely shortened. Especially in lands ravaged by nuclear war, frost would contribute to dramatically reduced crop yields and food supplies, threatening worldwide famine.(17)

Widespread famine from other causes is also possible. Fallout radiation and UV exposure could lead to mutations in food crops and decreased agricultural productivity. Furthermore, modern agricultural techniques depend on a complex technology of artificial fertilizers, hybrid grains, and petroleum-powered tractors. The probable disruption of this agricultural network by a nuclear conflict would also severely reduce crop yields.

The Congressional Office of Technology Assessment describes the immediate societal aftermath of a nuclear war as a "race for survival."(14) Survivors would depend on existing stores of food, water, and supplies. There would be a critical race between the depletion of such stores and the reconstruction of the agricultural and industrial capacity to replenish these essential supplies. Reconstruction would require years, and stores of necessary supplies are limited. It is not known if the race would be won or lost.

IV. CONCLUSIONS

To us, as physicians, medical students, biomedical scientists, and other health care professionals, it appears obvious that the medical consequences of any nuclear exchange would be catastrophic, involving numbers of casualties too large to be understood.

In the aftermath of even a single nuclear explosion on a major city, hundreds of thousands of people would be instantly annihilated and millions of survivors would suffer burns, bleeding, radiation sickness, and other injuries without hope of medical care. Many survivors would subsequently die from their wounds.

A nuclear war initiates many processes, the consequences of which appear only after many years or decades. Cancer deaths, inherited genetic defects, and damage to the delicate molecular balance of the atmosphere and biosphere are effects not precisely quantifiable, but predictable and real. A general nuclear war would cause social, political, and economic disruption incompatible with civilization. A traumatized population would confront severe shortages of food, water, and other supplies, which would present enormous, possibly insurmountable obstacles to recovery and reconstruction.

As health professionals, we have dedicated our lives to the alleviation of human suffering, to the prevention and cure of diseases, and to the nurturing of human life. Any form of nuclear war would lead to disastrous consequences contradictory to the essential spirit of medicine and health care.

When faced with an incurable, untreatable disease, physicians have historically acted to institute preventative efforts. In view of the imminent threat of nuclear war, our duty both as health professionals and as responsible citizens compels us to urge prevention. Prevention demands an immediate and sustained effort to eliminate the possibility that even a single nuclear weapon might ever be used, since even a limited nuclear exchange contains the inherent possibility of escalation into an all-out nuclear holocaust.

Prevention of nuclear war should be an essential foreign policy goal of every nation in the world. As health professionals, we have limited expertise in the complexities of negotiations to reduce nuclear arsenals. However, as concerned citizens, we think that:

1) The risks of nuclear war can be diminished only through negotiations and verifiable treaties among the superpowers;
2) The immediate goal of these negotiations and treaties should be a freeze on development, construction, testing, and deployment of nuclear weapons systems;
3) The ultimate goal of these negotiations and treaties should be periodic decreases in the size of nuclear weapon arsenals.

No effort to prevent a nuclear war can come too soon, only too late. We urge all citizens and government officals to initiate immediate actions to prevent a nuclear war. In today's volatile world, this becomes the ultimate responsibility to the generations of tomorrow.

REFERENCES

1. Aronow, Saul, Frank R. Ervin, and Victor W. Sidel, eds. *The Fallen Sky: Medical Consequences of Thermonuclear War,* Physicians for Social Responsibility, 1963.

2. Chivian, Eric, "Protective Measures: Active, Passive, Civil," Lecture, Harvard Medical School, for the course "The Health Aspects of Nuclear Weapons and War," (HMS course) March 18, 1982.

3. Committee for the Compilation of Materials on Damage Caused by the Atomic Bombs in Hiroshima and Nagasaki, *Hiroshima and Nagasaki*, tr. Eisei Ichikawa and David L. Swain, 1981.

4. Constable, John, "Burn Casualties," in *The Final Epidemic*, ed. for PSR by Ruth Adams and Susan Cullen, Educational Foundation for Nuclear Science, Chicago, 1981.

5. Geiger, H. Jack. "Illusion of Survival," in *The Final Epidemic.*

6. Hiatt, Howard, "The Clinical Picture," in *The Final Epidemic.*

7. International Physicians for the Prevention of Nuclear War, "Proceedings of the First Congress" (pamphlet), March 20-25, 1981.

8. Leaf, Alexander, "The Effect of a One-Megaton Bomb/Of All-Out War," Lecture, HMS course, February 25, 1982.

9. Lewis, Kevin, "The Prompt and Delayed Effects of Nuclear War," *Scientific American,* Vol. 241, No. 1, July 1979.

10. Lifton, Robert Jay, *Death in Life*, Simon and Schuster, New York, 1967.

11. Lindop, Patricia J., and J. Rotblat, "Consequences of Radioactive Fallout," in *The Final Epidemic.*

12. Lown, Bernard, Grand Rounds in Medicine at the Brigham and Women's Hospital, Boston, Massachusetts, January 22, 1982.

13. Mendelsohn, Everett, "The Science and Technology of Nuclear War," Lecture, HMS course, February 18, 1982.

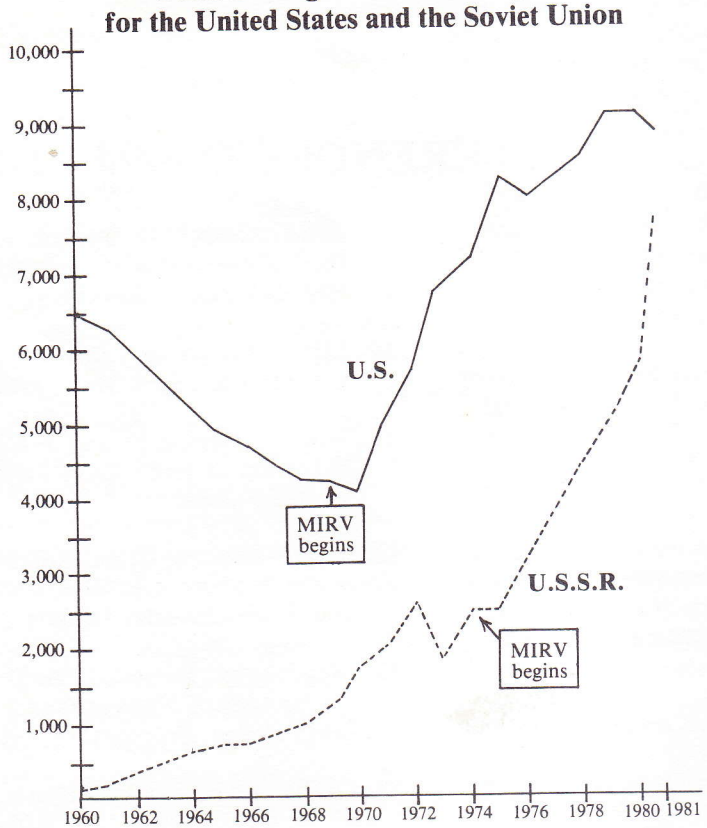
14. Office of Technology Assessment, Congress of the United States, *The Effects of Nuclear War*, 1979.

15. Physicians for Social Responsibility, *PSR Newsletter*, Vol. 1, No. 4., December 1980.

16. Tsipis, Kosta, "Physics of Weaponry and Effects on Ecology," Lecture, HMS course, February 11, 1982.

17. United Nations, *Nuclear Weapons: Report of the Secretary-General of the United Nations*, Autumn Press, 1980.

Total Strategic Nuclear Weapons for the United States and the Soviet Union



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The Nuclear War Study Group
Harvard Medical School
Vanderbilt Hall, Box 267a
107 Avenue Louis Pasteur
Boston, MA 02115

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